

# Space Technology & Exoplanets Exploration

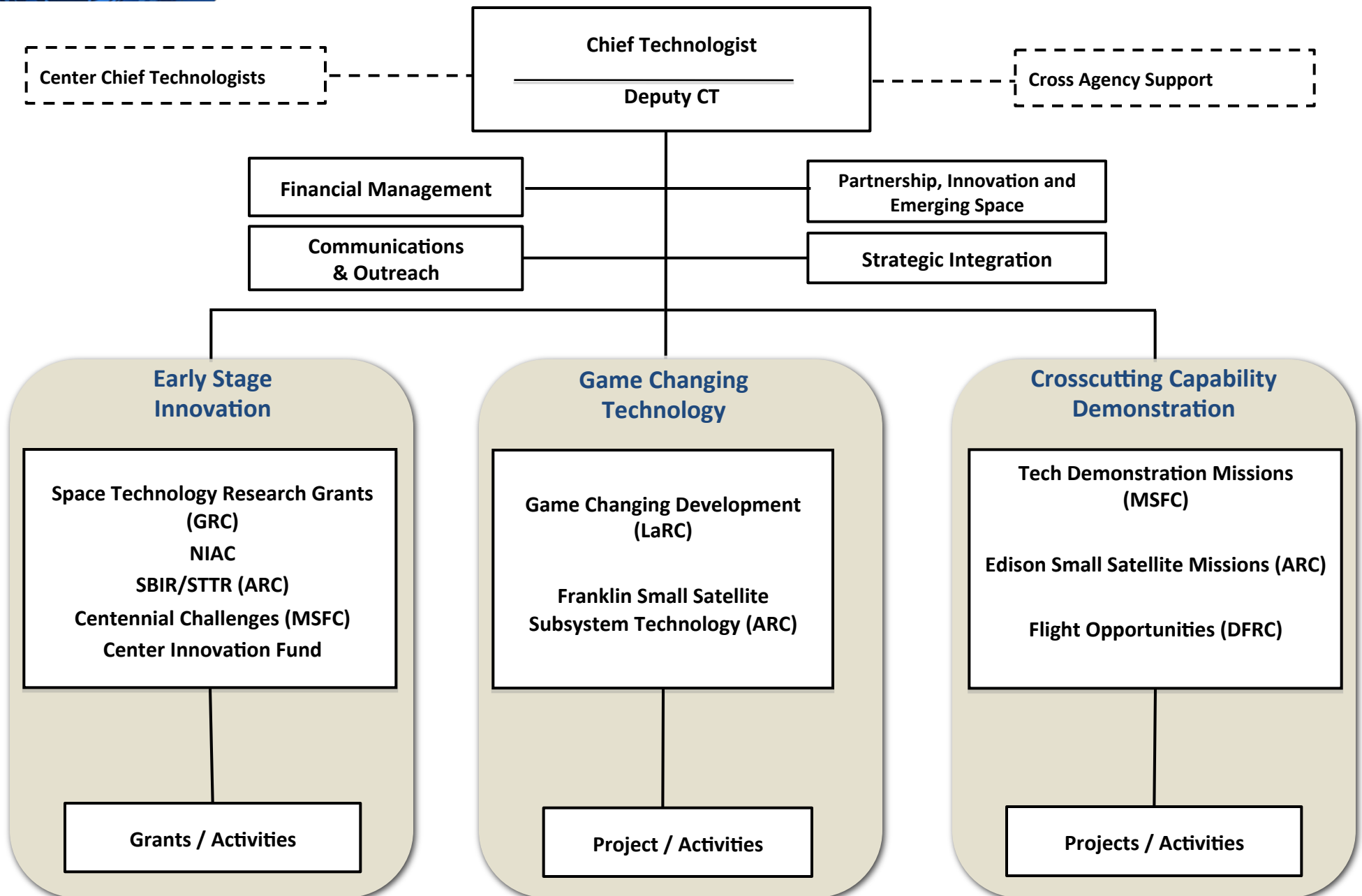
Presented at the ExoPAG Meeting, Alexandria, VA

Tibor Balint & James Reuther  
NASA HQ – Office of the Chief Technologist  
June 2, 2011

- About OCT
- Space Technology Drivers
- Grand Challenges
- Space Technology Roadmaps
- Exoplanets Technologies in the NASA ST Roadmap
- Exoplanets technology funding possibilities
- Questions

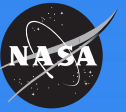
- **Space Technology is a budget line in the FY11 and FY12 President's request for NASA**
  - Consists of **10 technology development and innovation programs** that are broadly applicable to the Agency's aeronautics, science and exploration enterprises
  - Managed by Office of the Chief Technologist (**OCT**)
- **OCT has chosen to manage these 10 programs through the formation of 3 Divisions**
  - Early Stage Innovation
  - Game Changing Technology
  - Crosscutting Capability Demonstrations
- **Space Technology builds on the success of NASA's Innovative Partnerships Program (IPP)**
  - In FY11, IPP is integrated into Office of the Chief Technologist and the IPP budget is integrated into the Space Technology Program
- **Formulation of the Space Technology program is complete**
  - Formally approved by Administrator at July 29 Acquisition Strategy Planning meeting

# Office of the Chief Technologist Organization



- **Strategic Guidance**
  - Agency Strategic Plan
  - Grand challenges
  - Technology roadmaps
- **Full spectrum of technology programs that provide an infusion path to advance innovative ideas from concept to flight**
- **Competitive peer-review and selection**
  - Competition of ideas building an open community of innovators for the Nation
- **Projectized approach to technology development**
  - **Defined** start and end dates
  - Project Managers with **full authority and responsibility**
  - Project focus in selected set of **strategically defined capability** areas
- **Overarching goal is to re-position NASA on the cutting-edge**
  - **Technical rigor**
  - **Pushing the boundaries**
  - **Take informed risk**; when we fail, fail fast and learn in the process
  - Seek **disruptive** innovation
  - Foster an **emerging commercial space** industry

# Space Technology Drivers

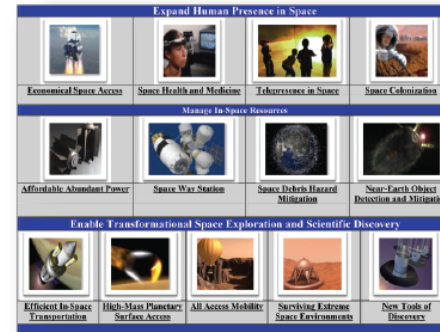


Strategic  
Guidance:

**Strategic  
Plan**



## Technology Roadmaps



**Grand  
Challenges**

**SPACE TECHNOLOGY**

**US Space  
Policy**

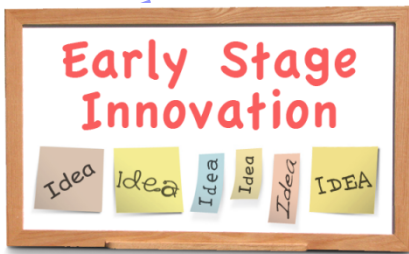
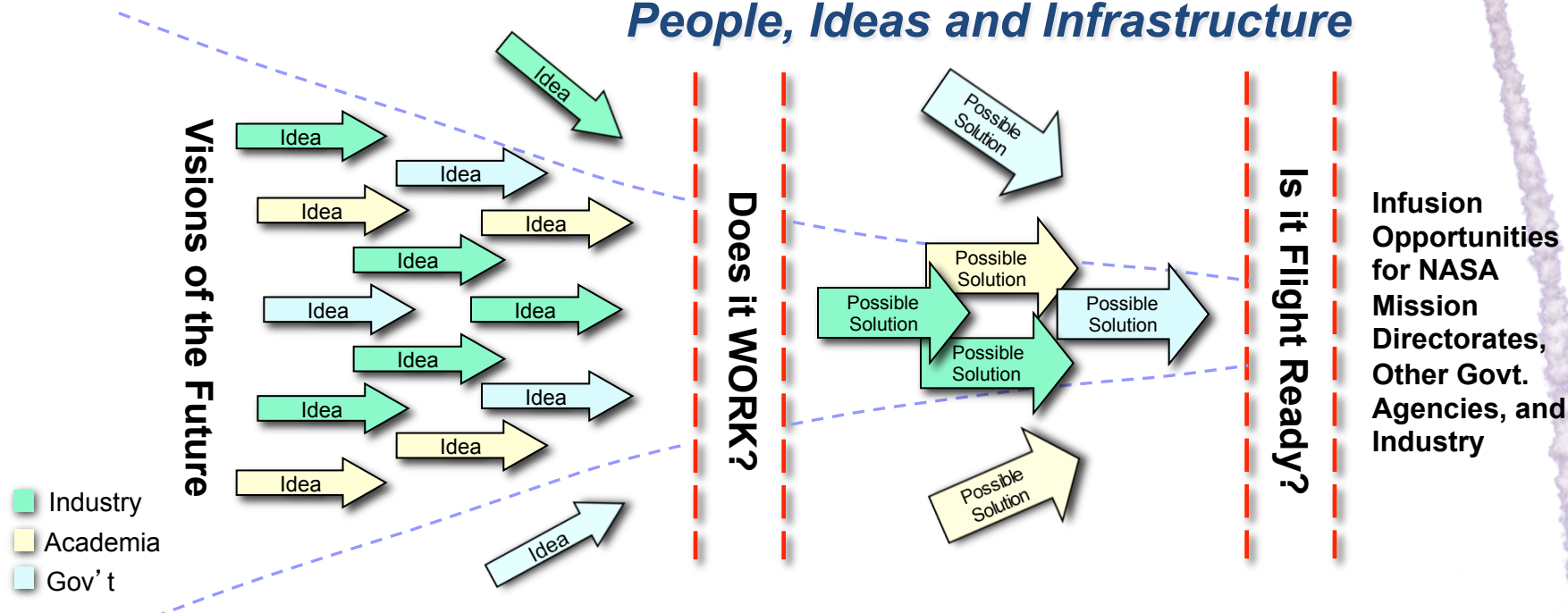


**National  
Needs**

# Space Technology: A Different Approach



## Engaging the Nation's Resources: People, Ideas and Infrastructure



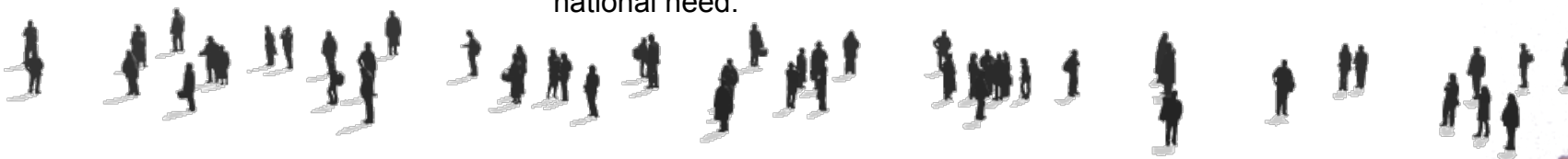
Creative ideas regarding future NASA systems or solutions to national needs.



Prove feasibility of novel, early-stage ideas with potential to revolutionize a future NASA mission and/or fulfill national need.



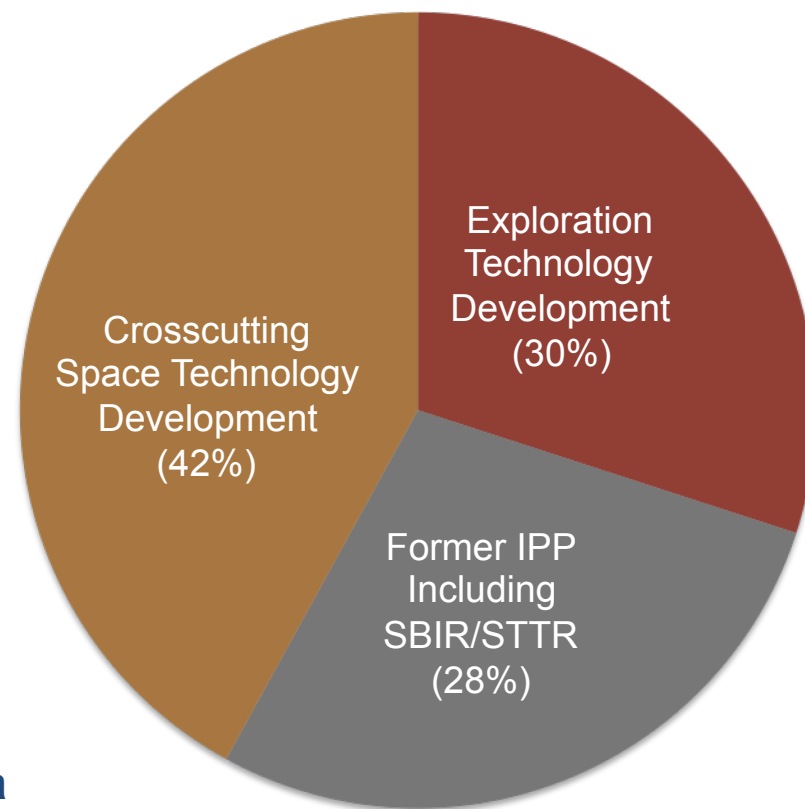
Mature crosscutting capabilities that advance multiple future space missions to flight readiness status



# Proposed FY 2012 Space Technology Budget



- In FY 2012, Space Technology is proposed at **approx. 5%** of the President's **\$18.7B request for NASA**.
- The **\$1024M** for Space Technology in FY 2012 includes:
  - The **SBIR/STTR** program and related technology transfer and commercialization activities (**\$284M**) funded in FY 2010 through NASA's Innovative Partnership Program
  - Movement of a majority of the **Exploration Technology Development and Demonstration** activities (**\$310M**) from the Exploration Systems Mission Directorate
  - The **Crosscutting technology development** activities (**\$430M**) proposed as part of the President's FY 2011 request.
- All of the Space Technology programs have been **carefully formulated** over the past year, and have deep roots in technology development approaches NASA has pursued in previous years.
- The **FY 2012 request for Space Technology provides a modest increase** above the level projected in the NASA Authorization Act of 2010, consistent with the Administration's priority on federal investments in research, technology and innovation across the Nation.
  - The FY2012 request for Space Technology compares with approximately \$800 million projected for these same activities in 2012 in the NASA Authorization Act of 2010




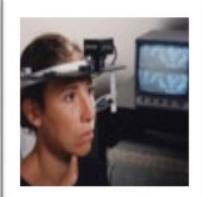

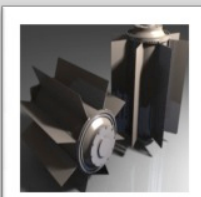




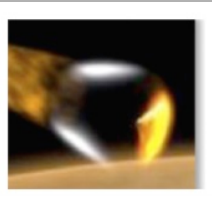
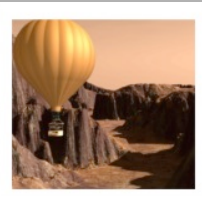
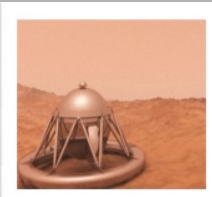
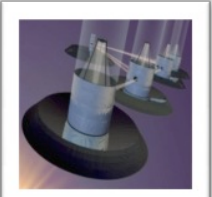
**NASA FY2012 Proposed  
Space Technology Budget  
(\$1024M)**

# Space Technology Grand Challenges



A set of important space-related problems that must be solved to efficiently and economically achieve our missions.

The Grand Challenges and ST Roadmaps will be used to prioritize the technology portfolio with an eye towards NASA's future

Expand Human Presence in Space				
				
<u>Economical Space Access</u>	<u>Space Health and Medicine</u>	<u>Telepresence in Space</u>	<u>Space Colonization</u>	
Manage In-Space Resources				
				
<u>Affordable Abundant Power</u>	<u>Space Way Station</u>	<u>Space Debris Hazard Mitigation</u>	<u>Near-Earth Object Detection and Mitigation</u>	
Enable Transformational Space Exploration and Scientific Discovery				
				
<u>Efficient In-Space Transportation</u>	<u>High-Mass Planetary Surface Access</u>	<u>All Access Mobility</u>	<u>Surviving Extreme Space Environments</u>	<u>New Tools of Discovery</u>

[http://www.nasa.gov/offices/oct/strategic\\_integration/grand\\_challenges\\_detail.html](http://www.nasa.gov/offices/oct/strategic_integration/grand_challenges_detail.html)



- **Historically NASA contributed** significantly to the **advancement of technologies** to meet both NASA missions and fuel the Nation's high tech economy
- **More recently**, funding and strategic guidance for NASA technology programs over the past two decades have endured **repeated change cycles**
- In Order for NASA to more effectively and efficiently develop space technologies moving forward, it is necessary to **establish a sustained set of clearly identified and prioritized technology development goals**
- The **NASA Space Technology Roadmap**, drafted by NASA, and reviewed and vetted for technology investment identification and prioritization by the NRC, will serve NASA as a decadal-like survey, to **provide sustained technology investment goals**.

# Space Technology Roadmaps

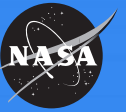
## Technology Area Breakdown Structure



TA01		• LAUNCH PROPULSION SYSTEMS	TA08		• SCIENCE INSTRUMENTS, OBSERVATORIES & SENSOR SYSTEMS
TA02		• IN-SPACE PROPULSION TECHNOLOGIES	TA09		• ENTRY, DESCENT & LANDING SYSTEMS
TA03		• SPACE POWER & ENERGY STORAGE	TA10		• NANOTECHNOLOGY
TA04		• ROBOTICS, TELE-ROBOTICS & AUTONOMOUS SYSTEMS	TA11		• MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING
TA05		• COMMUNICATION & NAVIGATION	TA12		• MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING
TA06		• HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS	TA13		• GROUND & LAUNCH SYSTEMS PROCESSING
TA07		• HUMAN EXPLORATION DESTINATION SYSTEMS	TA14		• THERMAL MANAGEMENT SYSTEMS

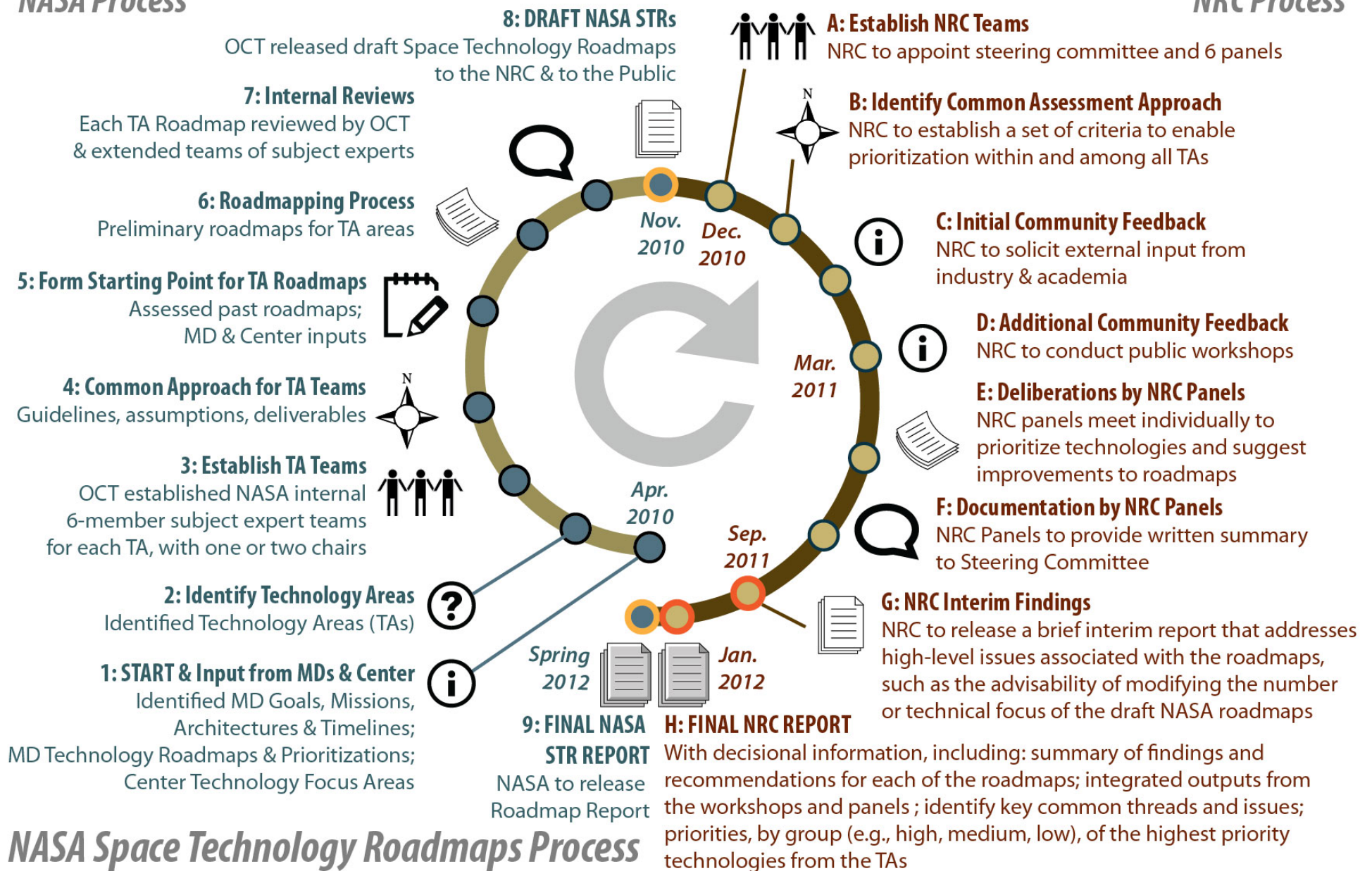
<http://www.nasa.gov/offices/oct/home/roadmaps/index.html>

# Space Technology Roadmap Process



## NASA Process

## NRC Process



## NASA Space Technology Roadmaps Process



# ExoPAG Relevant Technology Areas

## TA08 – Science instruments, Observatories & Sensor Systems



### TA01 • LAUNCH PROPULSION SYSTEMS

#### SOLID ROCKET PROPULSION SYSTEMS

- Propellants
- Case Materials
- Nozzle Structures
- Hybrid Rocket Propulsion Systems
- Fundamental Solid Propulsion Technologies

#### LIQUID ROCKET PROPULSION SYSTEMS

- LH<sub>2</sub>/LOX Based
- RP/LOX Based
- CH<sub>4</sub>/LOX Based
- Detonation Wave Engines (Closed Cycle)
- Propellants
- Fundamental Liquid Propulsion Technologies

#### AIR BREATHING PROPULSION SYSTEMS

- TBCC
- RBCC
- Detonation Wave Engines (Open Cycle)
- Turbine Based Jet Engines (Flyback Boosters)
- Ramjet/Scramjet Engines (Accelerators)
- Deeply-cooled Air Cycles
- Air Collection & Enrichment System
- Fundamental Air Breathing Propulsion Technologies

#### ANCILLARY PROPULSION SYSTEMS

- Auxiliary Control Systems
- Main Propulsion Systems (Excluding Engines)
- Launch Abort Systems
- Thrust Vector Control Systems
- Health Management & Sensors
- Pyro & Separation Systems
- Fundamental Ancillary Propulsion Technologies

#### UNCONVENTIONAL / OTHER PROPULSION SYSTEMS

- Ground Launch Assist
- Air Launch / Drop Systems
- Space Tether Systems
- Beamed Energy / Energy Addition
- Nuclear
- High Energy Density Materials/Propellants

### TA02 • IN-SPACE PROPULSION TECHNOLOGIES

#### CHEMICAL PROPULSION

- Liquid Storable
- Liquid Cryogenic
- Gels
- Solid
- Hybrid
- Cold Gas/Warm Gas
- Micro-propulsion

#### NON-CHEMICAL PROPULSION

- Electric Propulsion
- Solar Sail Propulsion
- Thermal Propulsion
- Tether Propulsion

#### ADVANCED (TRL 4-9) PROPULSION TECHNOLOGIES

- Beamed Energy Propulsion
- Electric Sail Propulsion
- Fusion Propulsion
- High Energy Density Materials
- Antimatter Propulsion
- Advanced Fission
- Breakthrough Propulsion

#### SUPPORTING TECHNOLOGIES

- Engine Health Monitoring & Safety
- Propellant Storage & Transfer
- Materials & Manufacturing Technologies
- Heat Rejection
- Power

#### TA03 • SPACE POWER & ENERGY STORAGE

##### POWER GENERATION

- Energy Harvesting (Chemical/Fuel Cells, Heat Engines)
- Solar (Photo-Voltaic & Thermal)
- Radioisotope
- Fission
- Fusion

##### ENERGY STORAGE

- Batteries
- Flywheels
- Regenerative Fuel Cells

##### POWER MANAGEMENT & DISTRIBUTION

- FDIR
- Management & Control
- Distribution & Transmission
- Wireless Power Transmission
- Conversion & Regulation

##### CROSS CUTTING TECHNOLOGY

- Analytical Tools
- Green Energy Impact
- Multi-functional Structures
- Alternative Fuels

### TA04 • ROBOTICS, TELE-ROBOTICS & AUTONOMOUS SYSTEMS

#### SENSING & PERCEPTION

- Stereo Vision
- LIDAR
- Proximity Sensing
- Sensing Non-Geometric Terrain Properties
- Estimating Terrain Mechanical Properties
- Tactile Sensing Arrays
- Gravity Sensors & Celestial Nav.
- Terrain Relative Navigation
- Real-time Self-calibrating of Hand-eye Systems

#### MOBILITY

- Simultaneous Localiz. & Mapping
- Hazard Detection Algorithms
- Active Illumination
- 3-D Path Planning w/ Uncertainty
- Long-life Extr. Enviro. Mechanisms
- Robotic Jet Backpacks
- Smart Tethers
- Robot Swarms
- Walking in Micro-g

#### MANIPULATION

- Motion Planning Alg., High DOF
- Sensing & Control
- Robot Arms (light, high strength)
- Dexterous Manipul., Robot Hands
- Sensor Fusion for Grasping
- Grasp Planning Algorithms
- Robotic Drilling Mechanisms
- Multi-arm / End-effector Manipulation
- Planning with Uncertainty

#### HUMAN-SYSTEMS INTEGRATION

- Crew Decision Support Systems
- Immersive Visualization
- Distributed Collaboration
- Multi Agent Coordination
- Haptic Displays
- Displaying Raw Data to Humans

#### AUTONOMY

- Spacecraft Control Systems
- Vehicle Health Mgmt/Diag Systems
- Human Life Support Systems
- Planning/Scheduling Resources
- Operations
- Integrated Systems Health Management
- FDIR & Diagnostics
- System Monitoring & Prognosis
- V&V of Complex Adaptive Sys
- Automated Software Generation
- Software Reliability
- Semi-autonomous Systems

#### AUTON. RENDEZVOUS & DOCKING

- Rendezvous and Capture
- Low impact & Androgenous Docking Systems & Interfaces
- Relative Navigation Sensors
- Robust AR&D GN&C Algorithms & FSW
- Onboard Mission Manager
- AR&D Integration & Standardization

#### RTA SYSTEMS ENGINEERING

- Human safety
- Refueling Interfaces & Assoc. Tools
- Modular / Serviceable Interfaces
- High Perf., Low Power Onboard Computers
- Environment Tolerance
- Thermal Control
- Robot-to-Suit Interfaces
- Common Human-Robot Interfaces
- Crew Self Sufficiency

### TA05 • COMMUNICATION & NAVIGATION

#### OPTICAL COMM. & NAVIGATION

- Detector Development
- Large Apertures
- Lasers
- Acquisition & Tracking
- Atmospheric Mitigation

#### RADIO FREQUENCY COMMUNICATIONS

- Spectrum Efficient Technologies
- Power Efficient Technologies
- Propagation
- Flight & Ground Systems
- Earth Launch & Reentry Comm.
- Antennas

#### INTERNETWORKING

- Disruptive Tolerant Networking
- Adaptive Network Topology
- Information Assurance
- Integrated Network Management

#### POSITION, NAVIGATION, AND TIMING

- Timekeeping
- Time Distribution
- Onboard Auto Navigation & Maneuver
- Sensors & Visual Processing Systems
- Relative & Prec. Navigation
- Auto Precision Formation Flying
- Auto Approach & Landing

#### INTEGRATED TECHNOLOGIES

- Radio Systems
- Ultra Wideband
- Cognitive Networks
- Science from the Comm. System
- Hybrid Optical Comm. & Nav. Sensors
- RF/Optical Hybrid Technology

#### REVOLUTIONARY CONCEPTS

- X-Ray Navigation
- X-Ray Communications
- Neutrino-Based Navigation & Tracking
- Quantum Key Distribution
- Quantum Communications
- SQIF Microwave Amplifier
- Reasonably Large Apertures

#### TA06 • HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS

##### ENVIRONMENTAL CONTROL & LIFE SUPPORT SYSTEMS & HABITATION SYS.

- Air Revitalization
- Water Recovery & Management
- Waste Management
- Habitation

##### EXTRAVEHICULAR ACTIVITY SYSTEMS

- Pressure Garment
- Portable Life Support System
- Power, Avionics and Software

##### HUMAN HEALTH & PERFORMANCE

- Medical Diagnosis / Prognosis
- Long-Duration Health
- Behavioral Health & Performance
- Human Factors & Performance

##### ENVIRONMENTAL MONITORING, SAFETY & EMERGENCY RESPONSE

- Sensors: Air, Water, Microbial, etc.
- Fire: Detection, Suppression
- Protective Clothing / Breathing
- Remediation

##### RADIATION

- Risk Assessment Modeling
- Radiation Mitigation
- Protection Systems
- Space Weather Prediction
- Monitoring Technology

### TA07 • HUMAN EXPLORATION DESTINATION SYSTEMS

#### IN-SITU RESOURCE UTILIZATION

- Destination Reconnaissance, Prospecting, & Mapping
- Resource Acquisition
- Consumables Production
- Manufacturing & Infrastructure Emplacement

#### SUSTAINABILITY & SUPPORTABILITY

- Logistics Systems
- Maintenance Systems
- Repair Systems

#### "ADVANCED" HUMAN MOBILITY SYSTEMS

- EVA Mobility
- Surface Mobility
- Off-Surface Mobility

#### "ADVANCED" HABITAT SYSTEMS

- Integrated Habitat Systems
- Habitat Evolution

#### MISSION OPERATIONS & SAFETY

- Crew Training
- Environmental Protection
- Remote Mission Operations
- Planetary Safety

#### CROSS-CUTTING SYSTEMS

- Modeling, Simulations & Construction Characterization
- Construction & Assembly
- Dust Prevention & Mitigation

#### TA08 • SCIENCE INSTRUMENTS, OBSERVATORIES & SENSOR SYSTEMS

##### REMOTE SENSING INSTRUMENTS / SENSORS

- Detectors & Focal Planes
- Electronics
- Optical Components
- Microwave / Radio
- Lasers
- Cryogenic / Thermal

##### OBSERVATORIES

- Mirror Systems
- Structures & Antennas
- Distributed Aperture

##### IN-SITU INSTRUMENTS / SENSOR

- Particles: Charged & Neutral
- Fields & Waves
- In-Situ

##### TA09 • ENTRY, DESCENT & LANDING SYSTEMS

##### AEROASSIST & ATMOSPHERIC ENTRY

- Rigid Thermal Protection Systems
- Flexible Thermal Protection Systems
- Rigid Hypersonic Decelerators
- Deployable Hypersonic Decelerators
- Instrumentation & Health Monitoring
- Entry Modeling & Simulation

### TA09 • ENTRY, DESCENT & LANDING SYSTEMS

#### DESCENT

- Attached Deployable Decelerators
- Trailing Deployable Decelerators
- Supersonic Retropropulsion
- GN&C Sensors
- Descent Modeling & Simulation

#### LANDING

- Touchdown Systems
- Egress & Deployment Systems
- Propulsion Systems
- Large Body GN&C
- Small Body Systems
- Landing Modeling & Simulation

#### VEHICLE SYSTEMS TECHNOLOGY

- Architecture Analyses
- Separation Systems
- System Integration & Analyses
- Atmosphere & Surface Characterization

#### TA10 • NANOTECHNOLOGY

##### ENGINEERED MATERIALS & STRUCTURES

- Lightweight Structures
- Damage Tolerant Systems
- Coatings
- Adhesives
- Thermal Protection & Control

##### ENERGY GENERATION & STORAGE

- Energy Storage
- Energy Generation

##### PROPULSION

- Propellants
- Propulsion Components
- In-Space Propulsion

##### SENSORS, ELECTRONICS & DEVICES

- Sensors & Actuators
- Nanoelectronics
- Miniature Instruments

##### TA11 • MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING

##### COMPUTING

- Flight Computing
- Ground Computing

##### MODELING

- Software Modeling & Model-Checking
- Integrated Hardware/Software Modeling
- Human-System Performance Modeling
- Science & Engineering Modeling
- Frameworks, Languages, Tools & Standards

##### SIMULATION

- Distributed Simulation
- Integrated System Lifecycle Simulation
- Simulation-Based Systems Engineering
- Simulation-Based Training & Decision Support Systems

##### INFORMATION PROCESSING

- Science, Engineering & Mission Data Lifecycle
- Intelligent Data Understanding
- Semantic Technology
- Collaborative Science & Engineering
- Advanced Mission Systems

### TA11 • MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING

#### ENVIRONMENTAL AND GREEN TECHNOLOGIES

- Corrosion Prevention, Detection, & Mitigation
- Environmental Remediation & Site Restoration
- Preservation of Natural Ecosystems
- Alternate Energy Prototypes

#### TECHNOLOGIES TO INCREASE RELIABILITY & MISSION AVAILABILITY

- Advanced Launch Technologies
- Environment-Hardened Materials and Structures
- Inspection, Anomaly Detection & Identification
- Fault Isolation and Diagnostics
- Prognostics Technologies
- Repair, Mitigation, and Recovery Technologies
- Communications, Networking, Timing & Telemetry

#### TECHNOLOGIES TO IMPROVE MISSION SAFETY/MISSION RISK

- Range Tracking, Surveillance & Flight Safety Technologies
- Landing & Recovery Systems & Components
- Weather Prediction and Mitigation
- Robotics / Telebotics
- Safety Systems

#### TA12 • MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING

##### MATERIALS

- Lightweight Structures
- Computational Design
- Flexible Material Systems
- Environment
- Special Materials

##### STRUCTURES

- Lightweight Concepts
- Design & Certification Methods
- Reliability & Sustainability
- Test Tools & Methods
- Innovative, Multifunctional Concepts

##### MECHANICAL SYSTEMS

- Deployables, Docking and Interfaces
- Mechanism Life Prediction Systems
- Electro-mechanical & Mechanical & Micromechanisms
- Design & Analysis Tools and Methods
- Reliability / Life Assessment / Health Monitoring
- Certification Methods

##### MANUFACTURING

- Manufacturing Processes
- Intelligent Integrated Manufacturing and Cyber Physical Systems
- Electronics & Optics Manufacturing Process
- Sustainable Manufacturing

##### CROSS-CUTTING

- Nondestructive Evaluation & Sensors
- Model-Based Construction & Sustainment Methods
- Loads and Environmental Effects

### TA13 • GROUND & LAUNCH SYSTEMS PROCESSING

#### TECHNOLOGIES TO OPTIMIZE THE OPERATIONAL LIFE-CYCLE

- Storage, Distribution & Conservation of Fluids
- Automated Alignment, Coupling, & Assembly Systems
- Autonomous Command & Control for Ground and Integrated Vehicle/Ground Systems

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#### TA14 • THERMAL MANAGEMENT SYSTEMS

##### CRYOGENIC SYSTEMS

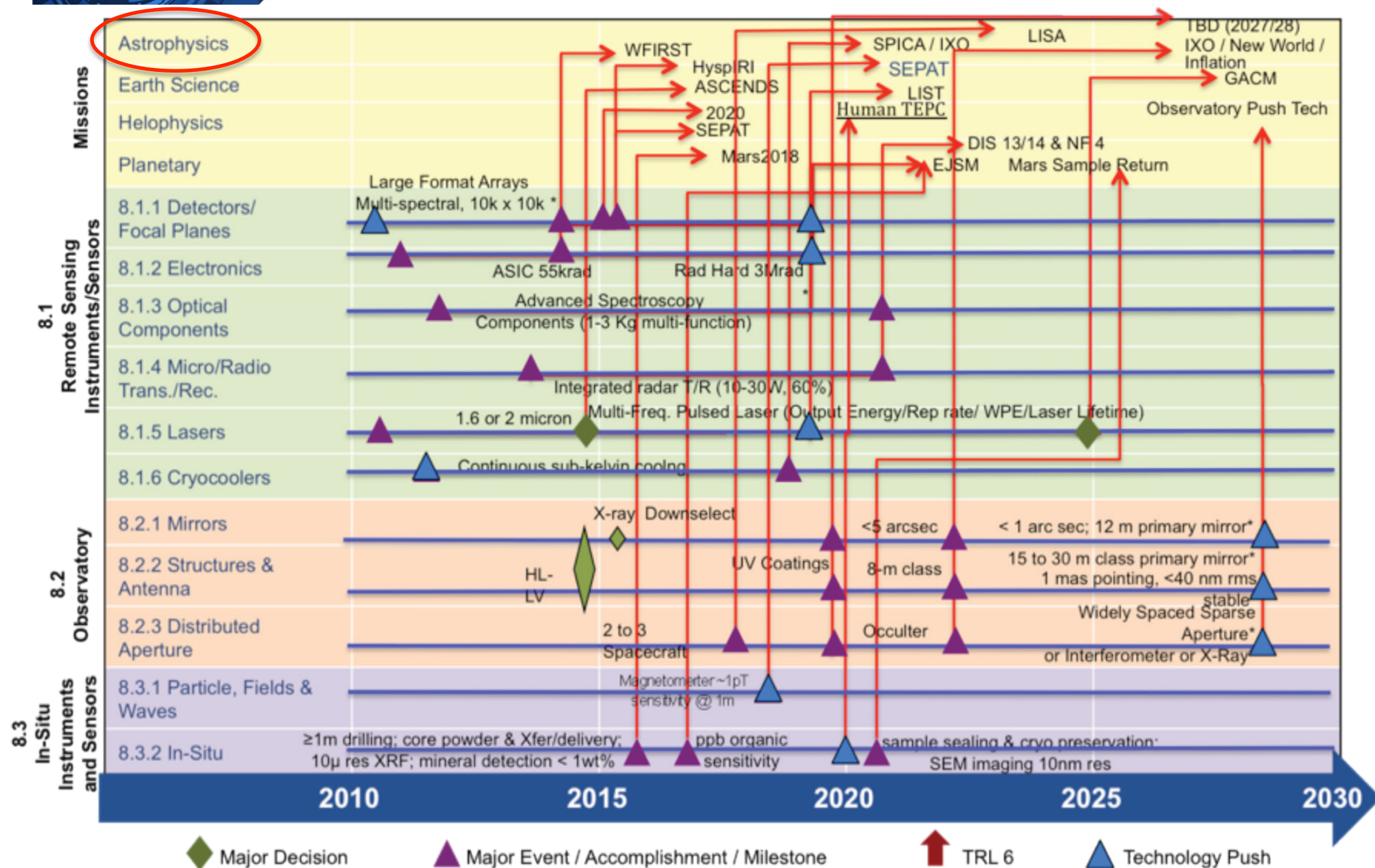
- Passive Thermal Control
- Active Thermal Control
- Integration & Modeling

##### THERMAL CONTROL SYSTEMS

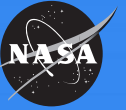
- Heat Acquisition
- Heat Transfer
- Heat Rejection & Energy Storage
- Thermal Protection Systems
- Entry / Ascent / Descent
- Plume Shielding (Convective & Radiative)
- Sensor Systems & Measurement Technologies

Space Technology Roadmaps STR • TABS  
TECHNOLOGY AREA BREAKDOWN STRUCTURE

# TA08 Technology Area Breakdown Structure



# How can OCT help the ExoPAG community?



- OCT Programs are
  - **Guided** (currently do not include ExoPAG related technologies), or
  - **Competed** (some programs are open for ExoPAG related technologies)
- They span across the Technology Readiness Level (TRL) spectrum
  - **Early Stage Innovation Division**: low TRL 1-3
  - **Game Changing Technologies Division**: low/medium TRL 3-5
  - **Crosscutting Capability Demonstrations Division**: medium/high TRL 5-7
- **ExoPAG** could submit proposals to OCT under any of these Divisions & their Projects
  - From fellowships, grants and low TRL advanced concepts
  - Through low/medium TRL component technologies
  - Potentially to medium/high TRL technologies up to flight demonstrations
- Solicitations where **ExoPAG could propose**
  - ESI: NASA Innovative Advanced Concepts – **NIAC** – low TRL (closed now)
  - GCT: Game Changing Developments – **GCD** – mid-TRL (still open)
  - CCD: Technology Demonstration Missions – TDM – mid/high TRL  
topics limited to (1) high bandwidth deep space comm/nav/timing; (2) orbital debris mitigation/removal; (3) advanced in-space propulsion; (4) autonomous rendezvous docking, close proximity operations and **formation flying**
- Please keep an eye on <http://www.nasa.gov/oct> & **NSPIRES** for new announcements



## Take Away Message

- NOW:
  - **NIAC** – NASA Innovative Advanced Concept – is **closing**
  - **Game Changing Development** is still **open** for mid-TRL technologies that have promise for disruptive innovations and applications to the space community
  - **TDM** is still **open** but to **topics are limited**, but
    - potential area for ExoPAG could be formation flying with segmented telescopes
- FUTURE:
  - OCT is planning many **more calls / solicitations over the next year or two**
  - **Be prepared** for those upcoming calls.
- ExoPAG needs to work to **identify a list of high priority technologies**.
  - What are the technologies that the community wants to get funded?
- If the ExoPAG community wants OCT to help fund technologies, OCT wants ExoPAG to:
  - **Work up the identification and rationale for the needed technologies**
  - **Highlight their link to the New Tools of Discovery Grand Challenge**



questions